Manuscript hess-2020-437
Response to Referee #1

Dear Referee #1:

Thank you for your insightful comments. Your feedback provides valuable improvements to our manuscript. Please find below our responses to your comments.

Acronyms
RC - Referee comments
AR - Author responses

Comments and responses

1. **RC**: The manuscript represents a contribution regarding the implementation of participatory modelling in vulnerable and disadvantaged communities to address eutrophication problems. Understanding and applying tools such as participatory system dynamics in different contexts is illuminating for research and practice and therefore, the manuscript offers a valuable work to be published in this special issue of the journal.

   AR: Thank you!

2. **RC**: However, the methodology and results associated to the multilevel storylines is really similar compared to the initial phases of conducting traditional participatory modelling processes to elicit causal loop diagrams. In this regard, it is required to strength the comparison of traditional approaches to elicit causal loop diagrams in participatory process and the storylines approach, or otherwise, presenting the storylines in their fair dimensions as an alternative to elicit causal loop diagrams in participatory process.

   AR: The approach we suggest is useful as it builds upon CLD construction methods to include more stakeholders meaningfully. We do not perceive it as an entirely new framework but rather as an extension to CLD building that can be implemented within marginalized communities. As pointed in the methodology, our research included iterations between storylines and CLDs. Storylines were used for two purposes:
   - **Extraction of information:** by definition, a storyline describes cause-and-effect relationships between events that impact certain components or actors. Therefore, storylines are compatible with CLDs. The main difference is that storylines provide more leeway for stakeholders to explain their inputs. For example, some stakeholders used metaphors or anecdotes to describe their observations. This is useful in the contexts of (1) less-literate and non-expert stakeholders who (a) might not be able to explicitly place their observations in the context of variables and links and (b) might feel intimidated by the technicalities of the CLD approach, and (2) Indigenous stakeholders who consider storytelling as a way to share knowledge. Although labelled as a ‘simplified version of a

storyline', we think that Figure 5 might be oversimplifying and misconstruing the flexibility of storylines. Therefore, we will improve the figure to include the intricacies of an extracted storyline.

- **Dissemination of results and science communication:** disseminating results in the form of storylines is more suitable for an audience of non-experts especially in the context of marginalized communities that include stakeholders who might not be comfortable with deciphering CLDs.

In the context of results, the difference lies in the ability of the methodology to (1) accommodate marginalized stakeholders who might have not been able to effectively participate otherwise and (2) the unique contributions of those stakeholders.

To address your comment, we will highlight the abovementioned points, eliminate terms and phrases that might exaggerate the novelty of the method (e.g. new framework), and emphasize that storylines used in parallel with CLDs allow for more inclusive stakeholder participation.

3. **RC**: The authors reviewed relevant literature regarding the building blocks of the approach adopted. Nonetheless, participatory modelling has been used in water resources management almost from its beginning and some relevant authors regarding the integration of these concepts were overlooked what perhaps lead the authors to not sufficiently acknowledge that practices quite similar to those developed in their research have been employed to: i) construct causal diagrams eliciting the stakeholders´ perspectives; and ii) take part in the whole cycle of system dynamic modeling.

   AR: We will add more studies pertaining to participatory SD modelling in water resources management (WRM) to the Background section (e.g. Enteshari et al., 2020; Pagano et al., 2019; Perrone et al., 2020; Stave, 2003; Tidwell et al., 2004). We showed some relevant studies (i.e. CLD building in WRM) that do not explicitly adapt their practices to effectively include marginalized stakeholders who might have been pertinent to corresponding case studies - e.g. Hassanzadeh et al. (2019) did not accommodate a multilingual context; Inam et al. (2015) used methods that require reading and writing.

   We would like to note that what we are looking for is not restricted to participatory methods that aim to elicit different perspectives. We are explicitly seeking approaches that aim to adapt participatory methodologies to include the effective participation of marginalized stakeholders (i.e. methods that are inclusive by design). We will highlight the aforementioned in key parts of the main text.

4. **RC**: The manuscript structure could be substantially improved. There are different ways the manuscript could be better structured. One could be to show a conceptual framework with the original building blocks, followed by a proposal of the integrated approach. Then, the methodology where this integrated approach is materialized could be described. After this, the results could be presented. The current way in which the

document is developed, with parts of the original approaches and the integrated approach appear in the introduction, the background and then the methodology, is not clear. Another path could be to develop the three proposed objectives in the results section that currently only addresses the implementation of integrated approach. In any case, sections 4.1 and 4.2 should not be part of the methodology since those are general descriptions of the approaches and not an account of the activities carried out to undertake the research process.

AR: Thank you for your suggestion. This will considerably improve the structure of our manuscript. We will add a section entitled 'Conceptual Framework'. This section will include the building blocks (the storytelling approach and the MLP framework) in addition to the integrated approach. We will remove the Background section. We will move Lines 125-151 and place them in the introduction between lines 93 and 94. Lines 152-235 will be adjusted to fit the section elaborating the storytelling approach in the new Conceptual Framework section.

5. In addition, more insight should be provided regarding the case selection, and how the research idea and problem emerged from the interaction between researchers and stakeholders.

   AR: We will elaborate more on that in Section 5.1. In brief, the eutrophication problem in the Lake Atitlan Basin has been a pressing environmental problem for more than a decade. The problem has been (1) especially amplified after cyanobacterial blooms covered 40% of the lake's surface in 2009 (Komárková et al., 2011; Weisman et al., 2018) and the endorsement of the Mega-collector project in 2018 (Esswein and Zernack, 2019) and (2) prioritized by research participants we met with (who were at the time associated with organizations working on projects connected to the lake) (e.g. Centro de Estudios Atitlan).

6. **RC**: Lines 145 -150
   Another approach, stakeholder created causal loop diagrams (CLDs), contain variables connected by links indicating causal relationships. Although CLDs have been previously applied in participatory research (Inam et al., 2015, 2017b), their construction requires reading and writing skills. Hence, they are ill-suited for involving less-literate participants in participatory model- building activities.
   This statement is not necessarily true. It is not necessarily the stakeholders those who formulate the CLDs. This approach of a facilitator building CLDs from interviews or focus groups and "translating" the information provided into the System Dynamics language is widely used in SD in WRM.

   AR: Thank you for pointing this out. We will address this by including and discussing studies that translated interviews or focus group discussions to CLDs (e.g. Giordano et al., 2020; Kim and Andersen, 2012; Pham et al., 2020). Also, we will highlight how our storyline methodology is different from researchers simply drawing a CLD based on an

interview. For example, the method applied in this study reduces the researcher's influence on the conceptual model and the number of ambiguous statements usually encompassed by interviews – which are two of the challenges faced when translating interviews to CLDs (Kim and Andersen, 2012).

RC: Line 269

Figure 1 Location of the study area in Guatemala. Created in QGIS (https://qgis.org/) using Esri (2009).
The map in Figure 1 needs to be substantially improved. The location of the study area in Guatemala and of Guatemala in America must be shown. Labels relevant only to the study area with Font of an appropriate size together with a grid of coordinates should be included.

AR: Thank you for pointing this out. We will revise the figure as per your suggestions.

7. **RC**: Lines 401 - 403

   The sign corresponding to each link indicates the type of relationship between the two variables: (+) indicates a direct relationship, while (-) implies an indirect one.
   This statement must be reworded. That is not the correct explanation of polarities for the causal relations in System Dynamics.

   AR: Thank you for pointing this out. We will rephrase the explanation.

8. **RC**: Lines 452 - 455
   These policies and BMPs are then simulated in a quantitative version of the model. The results are subsequently presented to stakeholders by members of the guidance team and discussed until an agreement on suitable solutions is reached. This paper does not cover the implementation of this step.
   Since a relevant feature of this work is the context of their application, involving marginalized and indigenous communities, it would be an important contribution to explain how model results were discussed and communicated to these stakeholders, which is relevant since the authors expressed that most of them cannot read or write.

   AR: Thank you for your comment. We will provide a brief explanation. In brief, the disseminated information is synthesized in a comprehensive narrative and communicated using storylines that appeal to non-expert audiences.

9. **RC**: Line 474
   Table 1: Demographics of project participants
   It would be convenient to expand the information on the number of participating indigenous communities and their different languages

   AR: We will expand the table to include the number of participating Kaqchikel, Tz'utujil, and K'iche stakeholders.

10. **RC**: Lines 511 – 512
    From the Macro-level storylines elicited from primary researcher participants, the authors concluded that the model should address the eutrophication problem of Lake Atitlán. According to that statement ¿how this research fits within a real participatory approach in which external agents (researchers) should have a facilitating role in a process through which the relevant stakeholders reflect, deliberate and are empowered to make decisions, rather than a role of extracting information from stakeholders and make decisions for them?

AR: Thank you for your comment. We agree that the term 'conclude' indicates that the researchers have made a unilateral decision. Therefore, we will rephrase this sentence.

- As mentioned in point 5 above, the problem has been prioritized by researcher participants who themselves have been involved in projects associated with the lake's eutrophication.
- The goal of the activity was to support community-based decision-making, especially by allowing stakeholders to communicate their perspectives, needs, and priorities.
- Members of the guidance team were aware that this presented a learning opportunity for them as well and sought to remain cognizant of their positionality in the research setting.

We will highlight the aforementioned points in the text.

11. **RC**: Figure 7
    Assess whether there is a feedback loop between "crop productivity" and "use of inorganic fertilizers and pesticides"
    Improve the figure so that the polarity between "irrigation efficiency" and "untreated wastewater can be observed".

    AR: Thank you for pointing this out. After we assessed the interactions between crop productivity and the consumption of inorganic fertilizers and pesticides, we have found that a feedback loop between the two variables exists. In general, the increased use of inorganic fertilizers and pesticides increases crop productivity (De Ponti et al., 2012). However, this was not mentioned by stakeholders and therefore, we will be consulting agriculturists/farmers who participated in the activity to validate the addition of the feedback loop. We will add relevant justification to the text.

    We believe you meant "water shortage" instead of untreated wastewater. If so, we will revise as suggested.

12. **RC:** Figure 8
    Improve the figure so that the polarity between "WWTP" and "untreated wastewater" can be observed.
    Use the term in full for WWTP
    Improve the figure so that the polarity between "available land" and "septic tanks" can be observed.
    correct typo in septic tanks

Correct the polarity between Jobs and Poverty. This polarity should be negative, not positive

AR: Thank you for pointing this out. We will revise the figure as per your suggestions.

13. **RC:** Figure 11
Is confusing that a relation can be reinforcing and balancing at the same time. Please clarify.

AR: Figure 11 displays a **generalized relationship** between economic prosperity and nutrient enrichment. The CLD on the right shows 2 loops: 1 balancing and 1 reinforcing. The figure is used to highlight feedback loops.

For both loops, and as explained in the Consequences section (Lines 555-565), the causal link corresponding to the impact of nutrient enrichment on economic prosperity is negative. This causal link is generalized and does not contain intermediaries since the point of the figure is to elaborate on the feedback (i.e. the impact of economic prosperity on nutrient enrichment).

Figure 11 (a): Some stakeholders stated that economic prosperity increases potential investments in WWTPs which reduces the discharge of untreated wastewater, consequently decreasing nutrient enrichment. This decrease in nutrient enrichment would lead to an increase in economic prosperity. The causal link corresponding to the impact of economic prosperity on nutrient enrichment is negative. Therefore, the relationship between economic prosperity and nutrient enrichment in this case is represented by a reinforcing loop (Fig. 11 (a)).

Other participants implied that economic prosperity increases investments in tourism businesses, which increases the number of tourists, consequently increasing the amount of untreated wastewater. This leads to an increase in nutrient enrichment which would cause a decrease in economic prosperity. The causal link corresponding to the impact of economic prosperity on nutrient enrichment is positive. Therefore, the relationship between economic prosperity and nutrient enrichment in this case is represented by a balancing loop (Fig. 11 (b)).

Both processes were the result of the inclusive participatory process and show the added value of incorporating marginalized stakeholders since the balancing loop between the two variables was exclusively identified by Indigenous stakeholders. Additionally, the delineation of both relationships shows that all potentially valid points can be represented explicitly in the model (which reinforces the point of inclusivity). However, we acknowledge that one of the two loops will dominate model behaviour. This will depend on model quantification.

To make the figure clearer and less confusing we will:

- Add intermediaries to the causal link corresponding to the impact of economic prosperity on nutrient enrichment
- Provide a clearer explanation in the caption
- Replace the current example (the loops on the right) with two examples mentioned within lines 570-587 and refer to the figure right next to the examples it represents
- Emphasize that the figure represents a generalized relationship
- Mention that model quantification will show which of the two loops will dominate model behaviour

References

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